A New Validated Model to Estimate GHG Emissions for Dairy Farms in California: Results and Application for Statewide Emission Estimates

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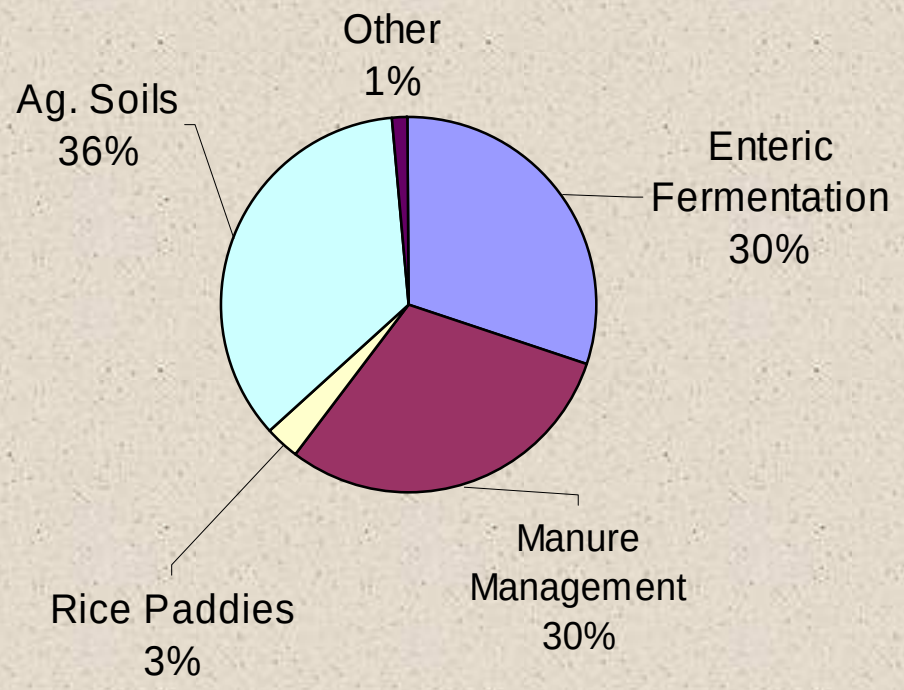
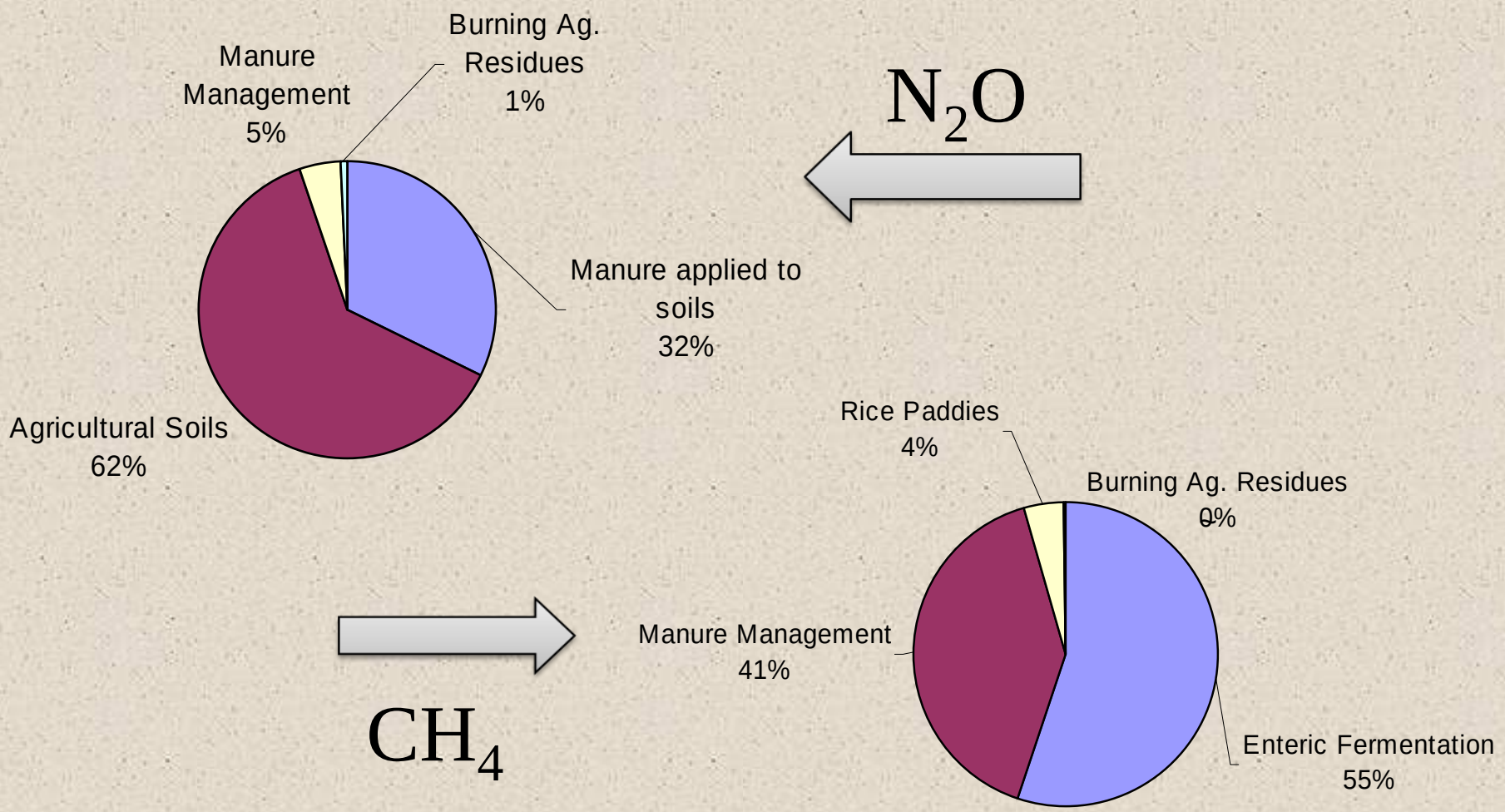
Why focus on Dairies?

- California GHG Emission Inventory:
  - Agriculture ~5% total emissions
  - 2004 Ag. Inventory = 23.09 MMT CO_2eq



Source: ARB GHG Emission Inventory

Agricultural Sources of CH_4 and N_2O



Talk Outline

- Project Goals
- Biogeochemical process model – Manure-DNDC
- Measurements of GHG emissions: Enteric CH4 and N2O and Drylot N2O
- Model Validation
- Results for California
- Conclusions/Next Steps

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Project Goals

- Modify an existing “process-based” biogeochemical model (DNDC) for estimating CH4, NH3, NO, N2O emissions from dairy systems in California.
- Collect field data to calibrate and validate this model
- Build GIS databases on soils, climate, dairy locations, and manure management.
- Apply the model to estimate emissions across California. Note: model is designed for both regional and single farm simulations.

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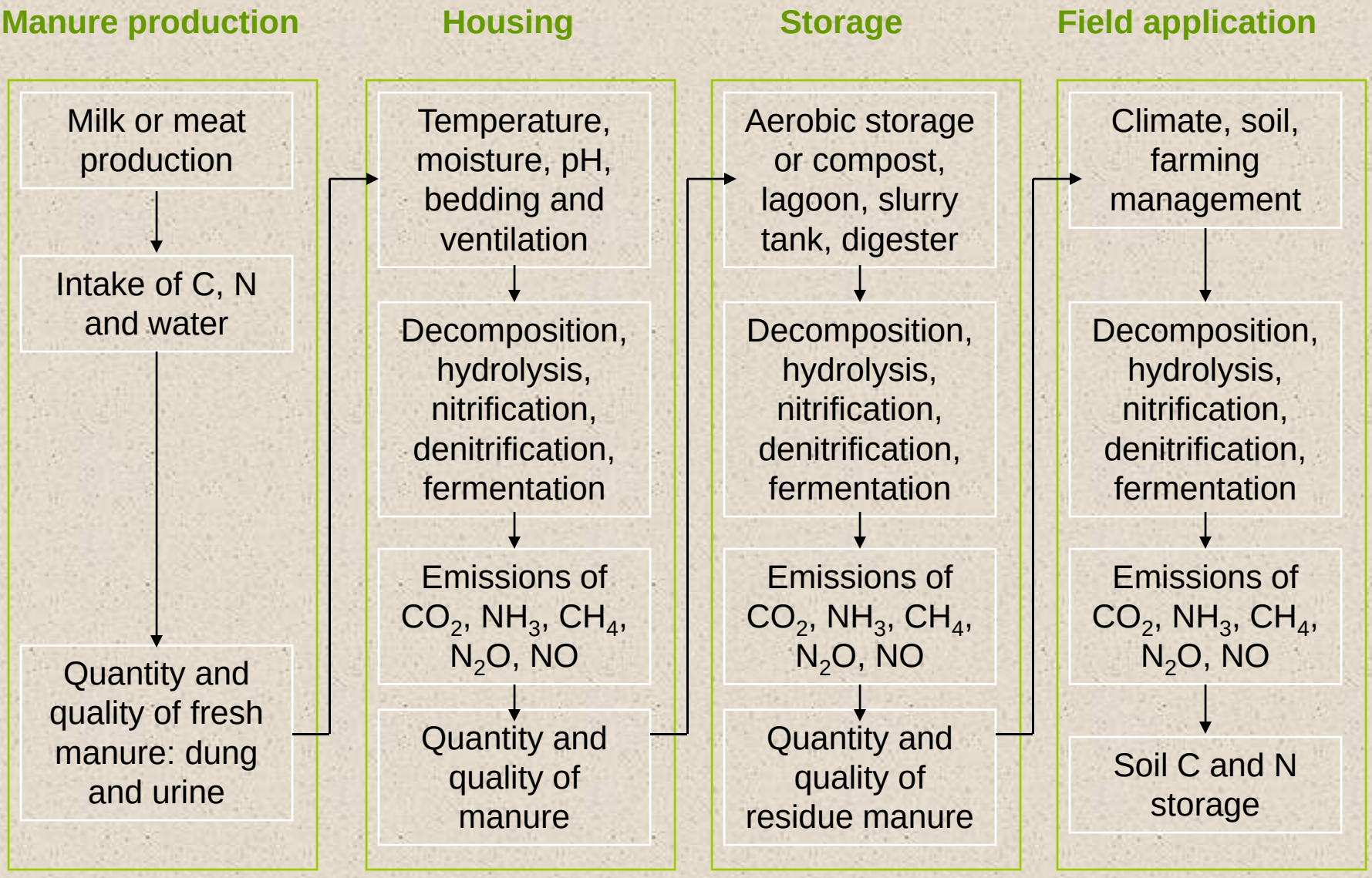
Role of Process-based Models

- Accurate assessment of air emissions from dairies with emission factors is difficult due to:
  1. high variability in the quality and quantity of animal waste, and
  2. numerous factors affecting the biogeochemical transformations of manure during collection, storage and field application.
- Measurement programs are essential but expensive and thus not feasible for monitoring and emission inventories.
- Therefore, process-based models that incorporate mass balance constraints are needed to extrapolate air emissions in both space and time (NRC, 2003).

Why DNDC Model?

- Contains algorithms for both anaerobic and aerobic soil environments
- Simulates full range of biogeochemical processes: decomposition, hydrolysis, nitrification, denitrification, ammonium adsorption, chemical equilibriums of ammonium/ammonia, and gas diffusion
- Well validated across a wide range of agroecosystems and is currently being used for national GHG emission inventories and mitigation studies worldwide.

Structure of Manure-DNDC



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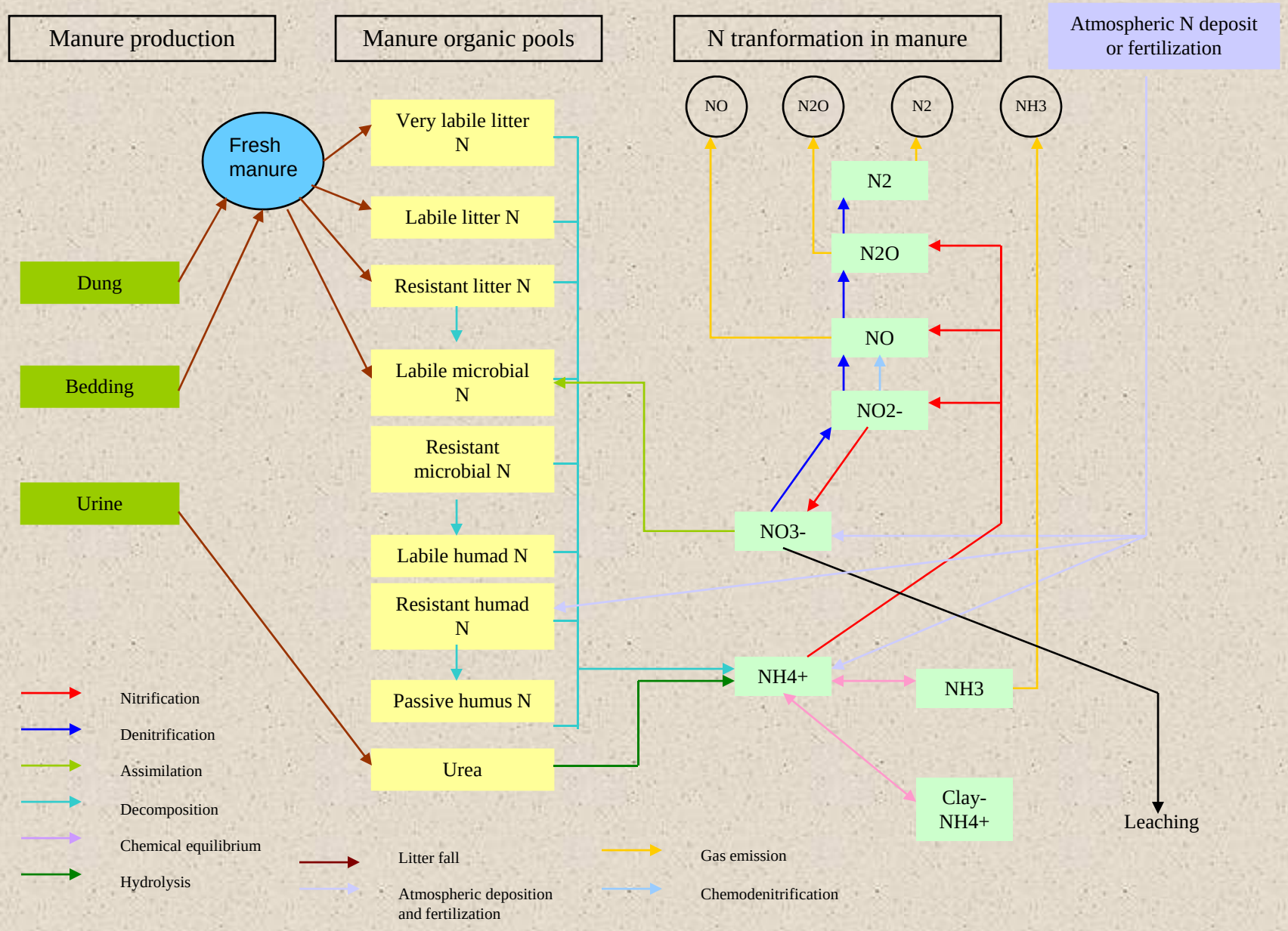
Nitrogen Biogeochemistry of Manure



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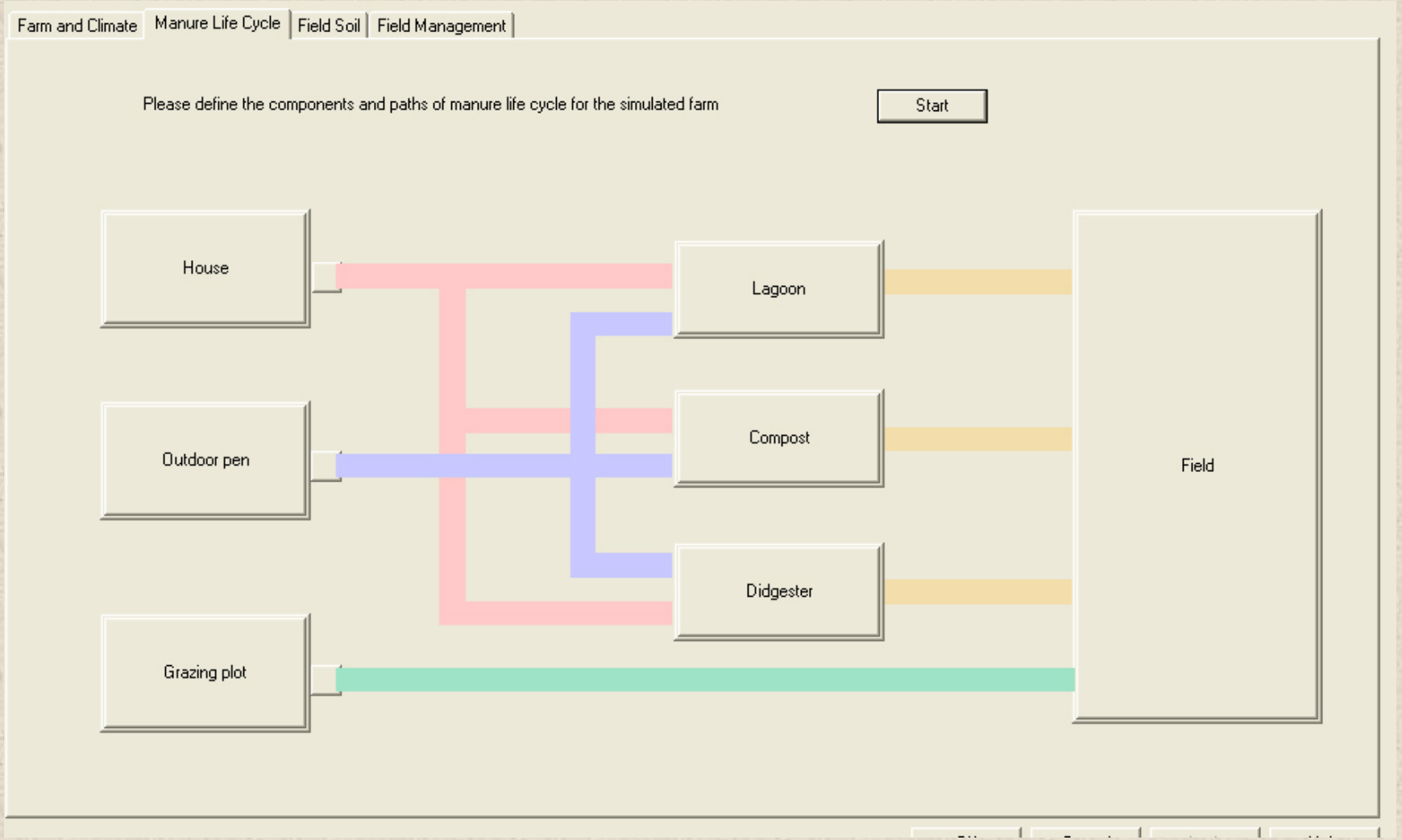
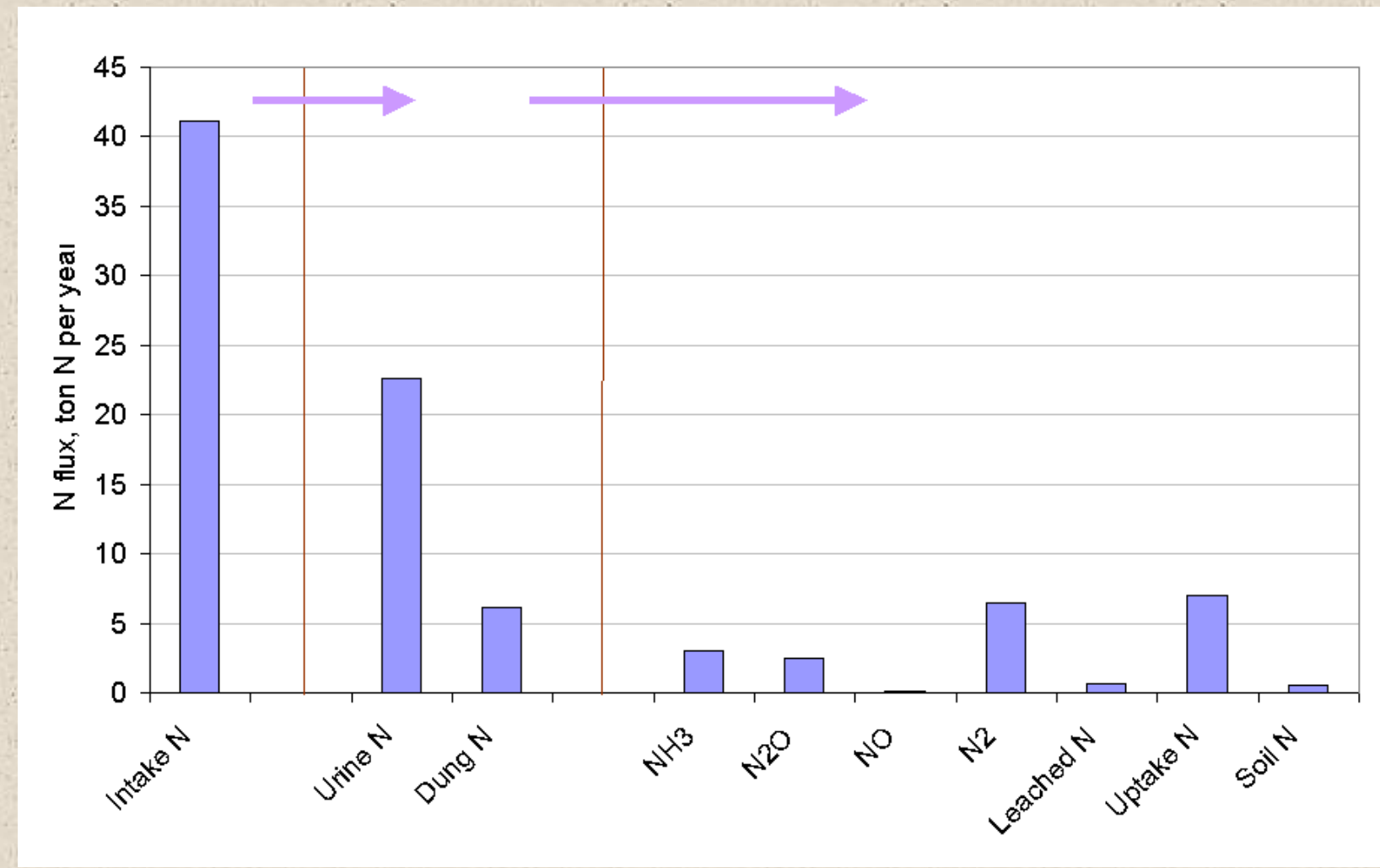
PC Menu Based Tool



Mass Balance Approach: Tracking Nitrogen



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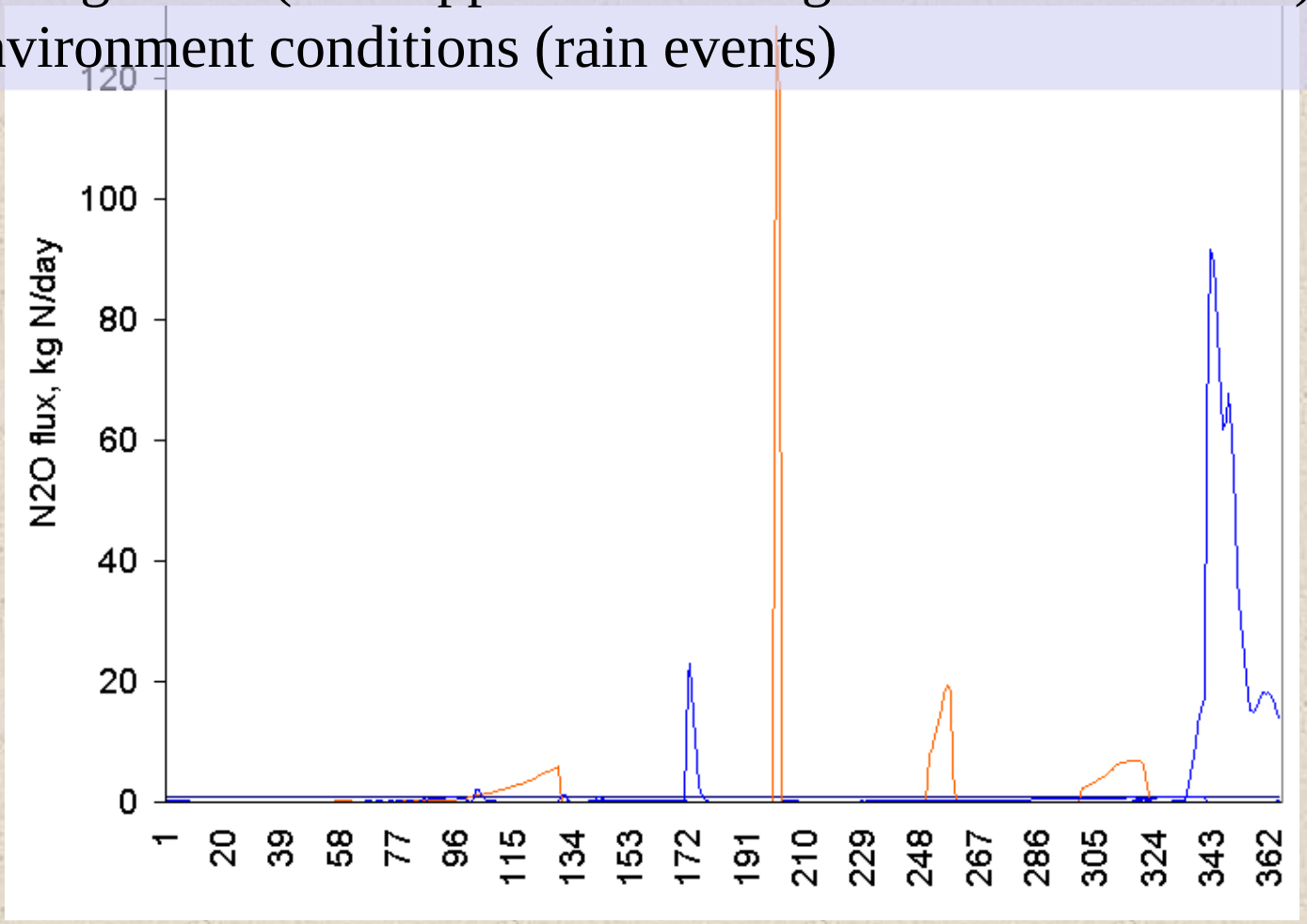
Daily Time Steps: Episodic Nature of N2O Emissions

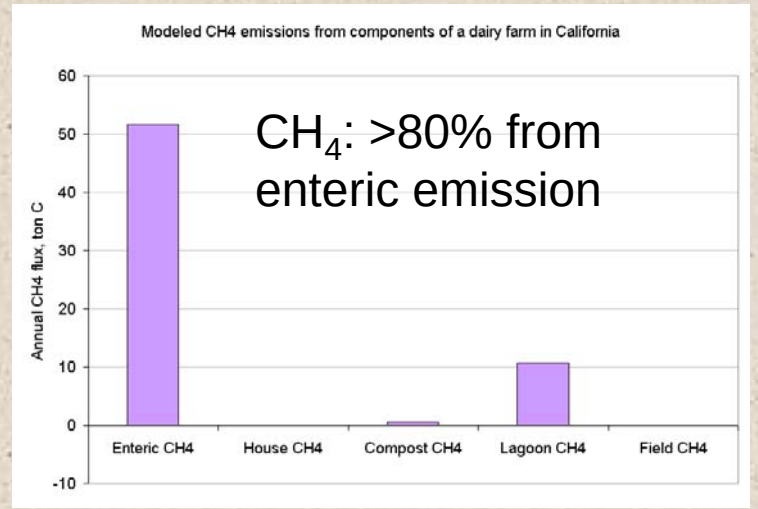
Peaks due to

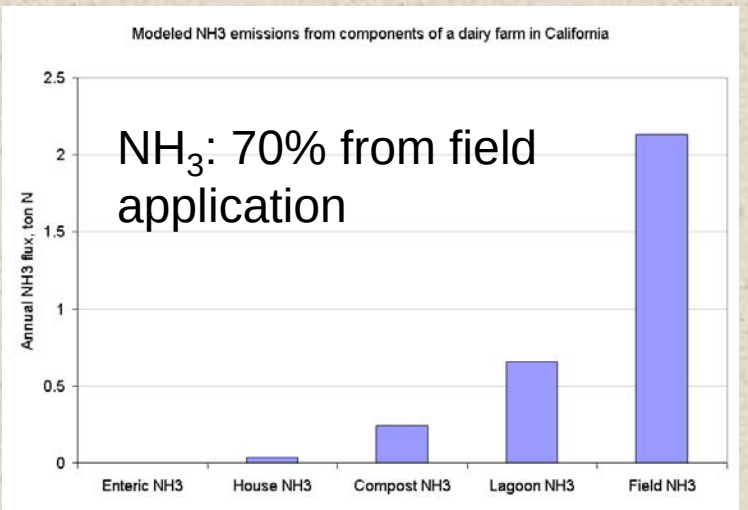
✓management (land application of lagoon water/fertilizer)

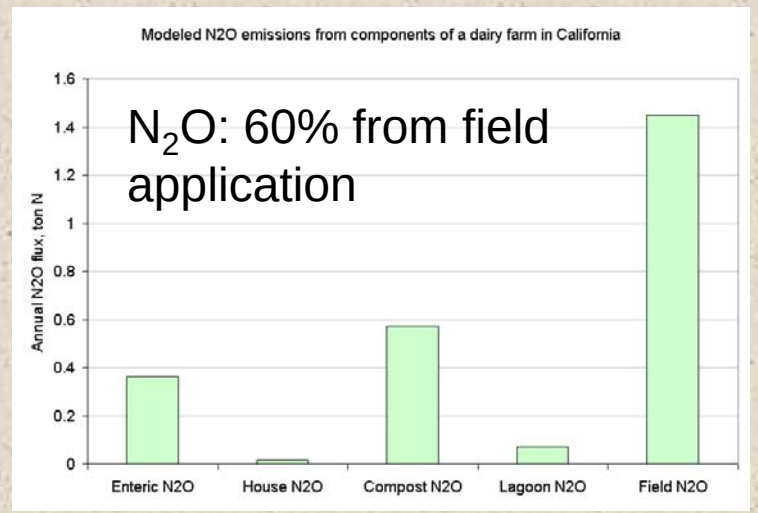
✓environment conditions (rain events)

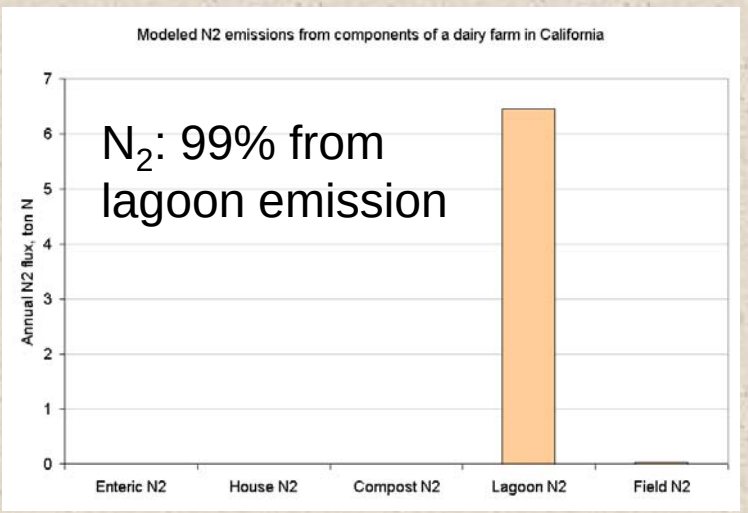


Gas Source Assessment: Manure-DNDC quantifies gas emissions from each component of the dairy

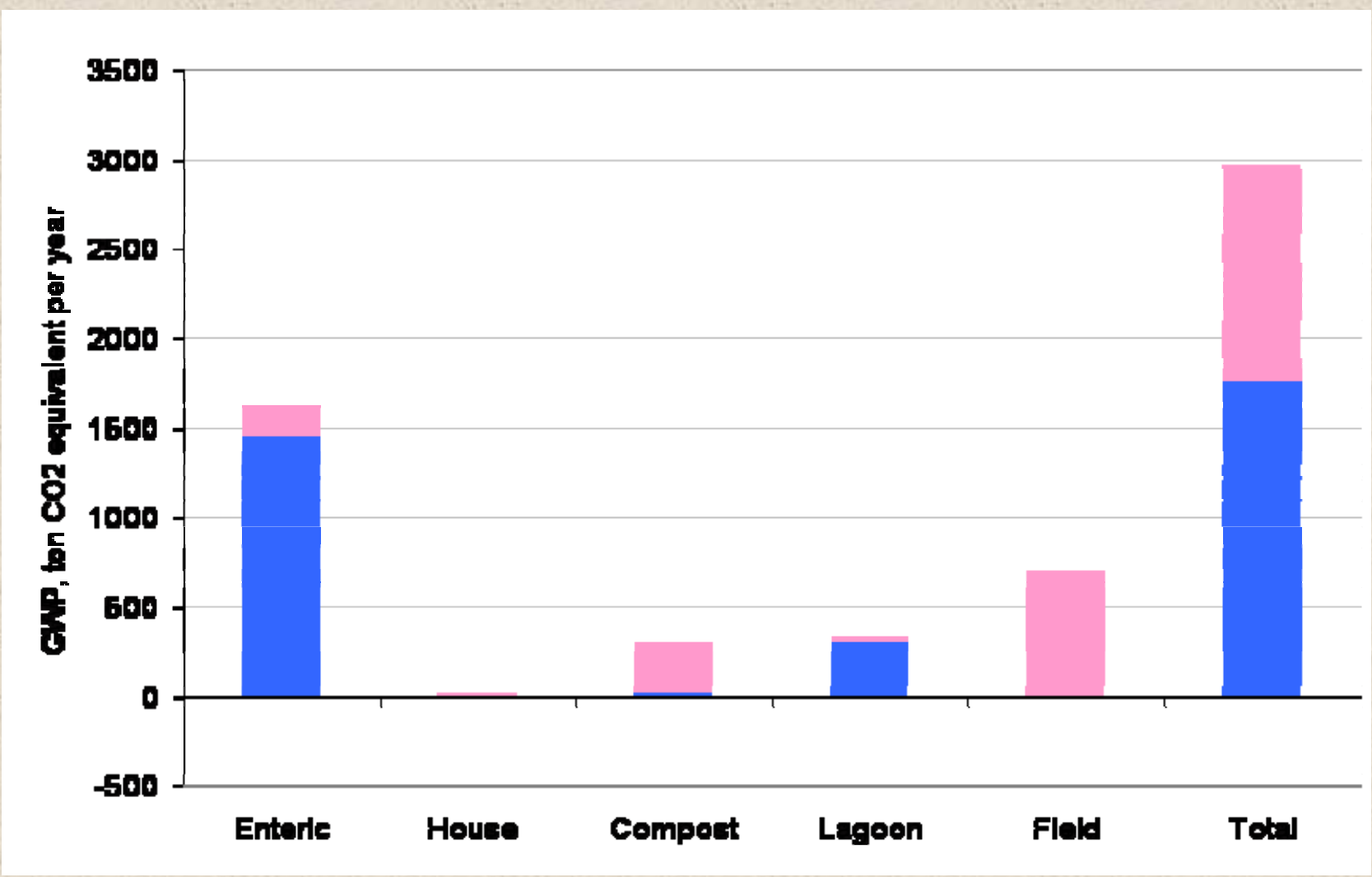








Full GHG Accounting by Dairy Component and Farm



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Field Measurements

- Environmental Chamber Studies: measured GHG emissions from cows and fresh waste.
  - Assessed impact of diets and lactation stages on enteric emissions
- Cattle Pen Enclosures
  - Simulate drylot facility with cement feed apron.
  - Measured total emissions (enteric, fresh waste, and fresh manure pack (upto 14 days)
- CSUF Drylot: Development and testing FTIR system

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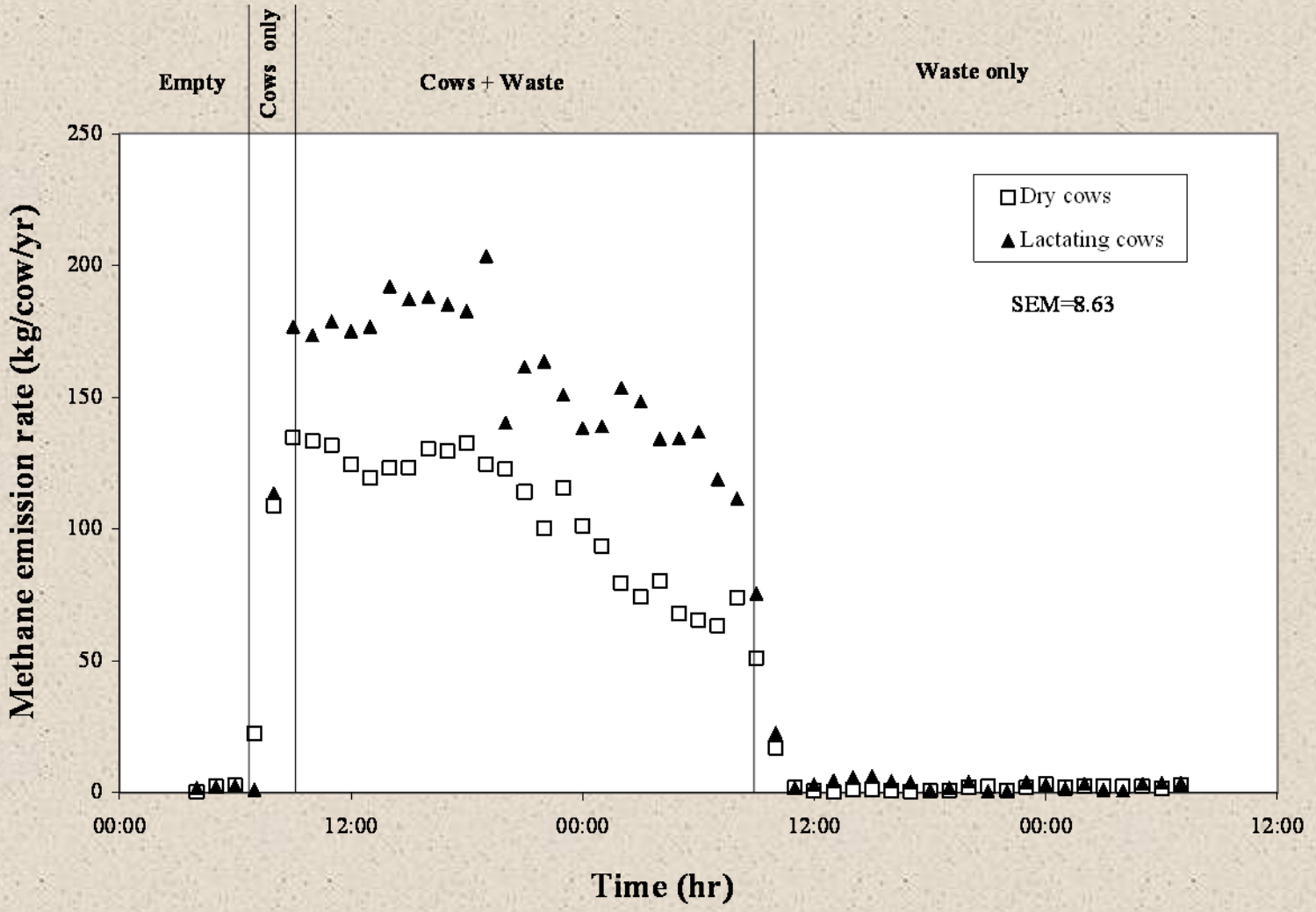
CH4 Results: Enteric and Fresh Waste



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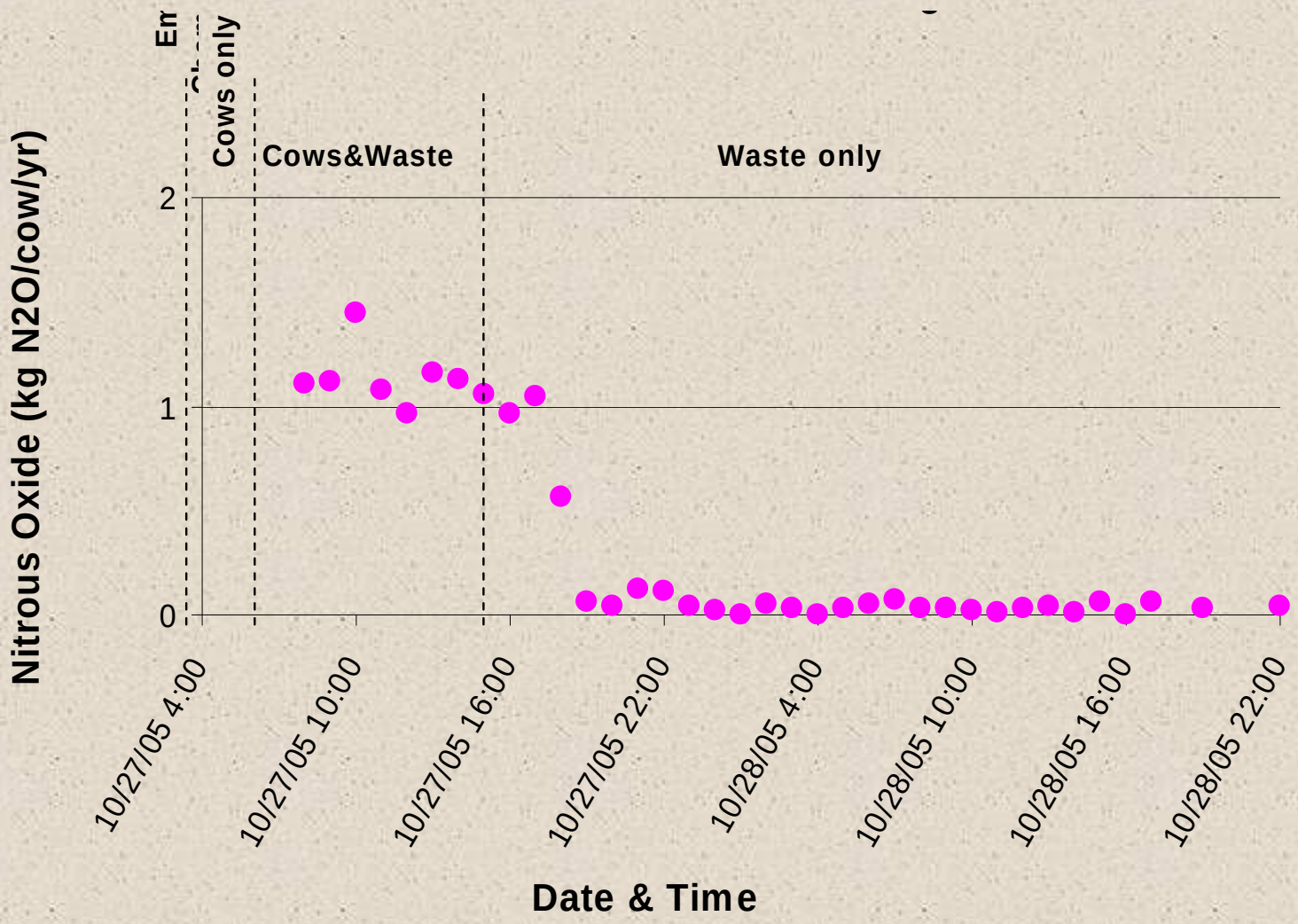
N2O Results: Enteric and Fresh Waste



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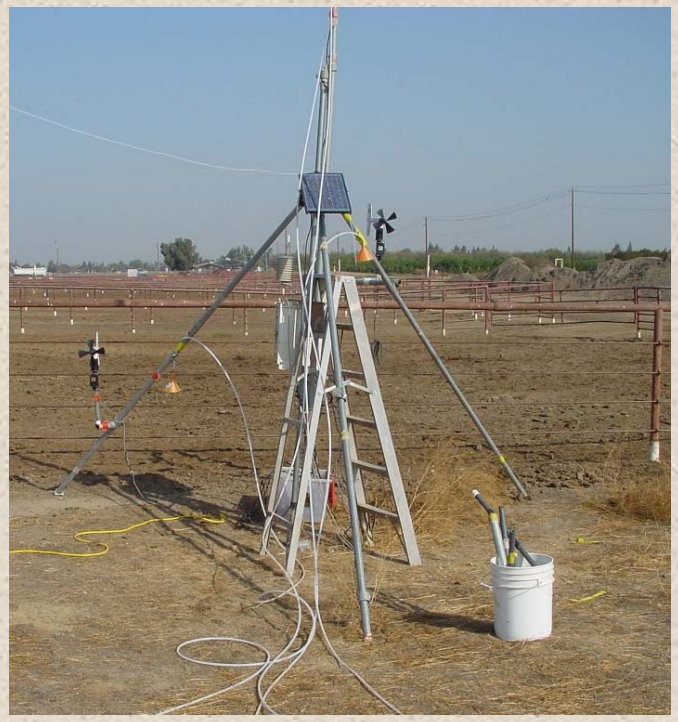
Drylot Measurements at CSUF Dairy

- Used FTIR
- Sampled at 4 elevations
  - 1,2,5 and 10m
- Fluxes gradient approach



Drylot N_2O Measurements

- Highly variable in space and time.
- Ranged from 0.04 to 1.7 kg N_2O/ha/day, averaged ~0.3 kg N_2O/ha/day
- Simulated Rain event: increased N2O fluxes by order of magnitude, effect was short term (1 day)
- Better results with static chamber measurements than the FTIR flux gradient approach.

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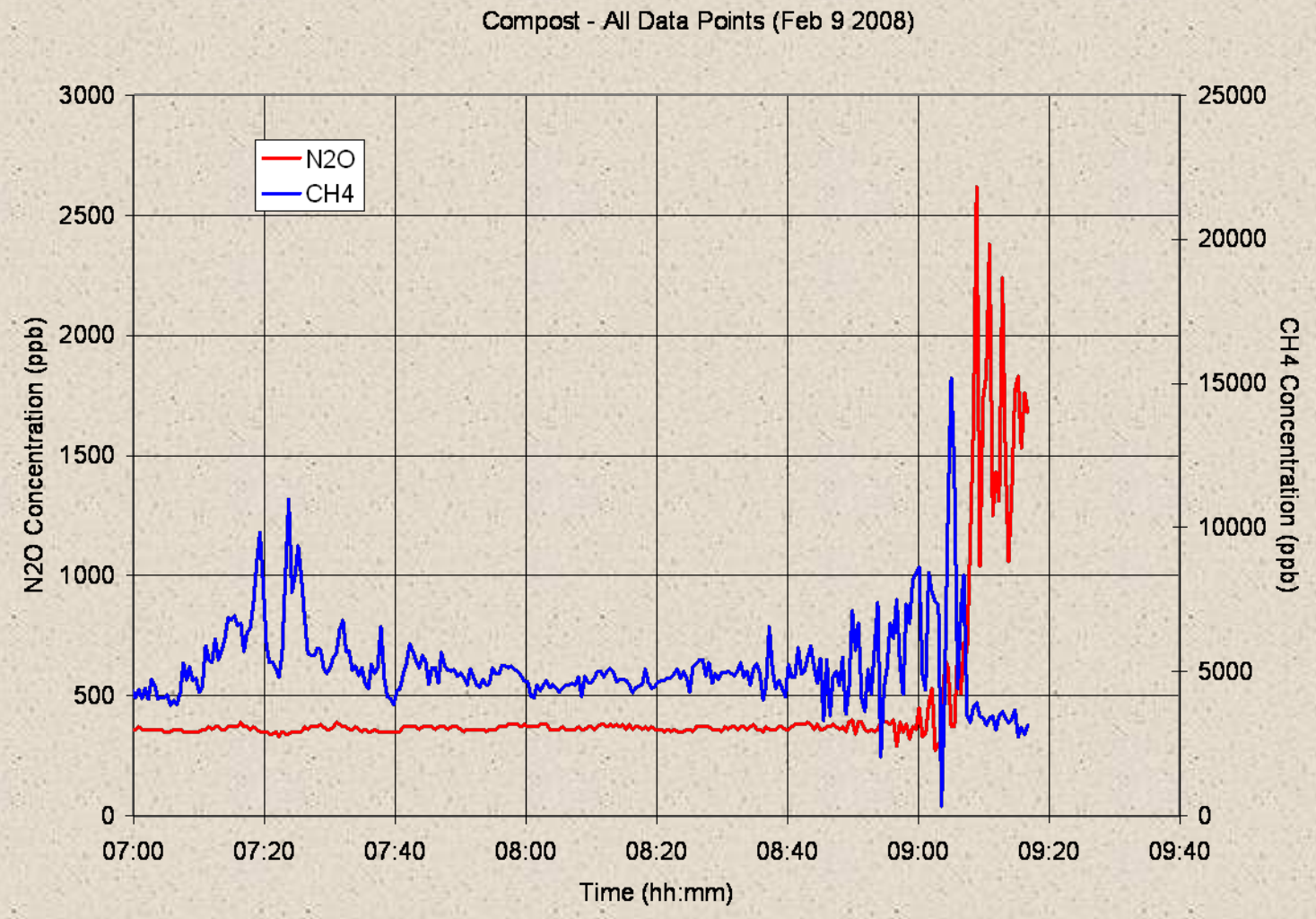
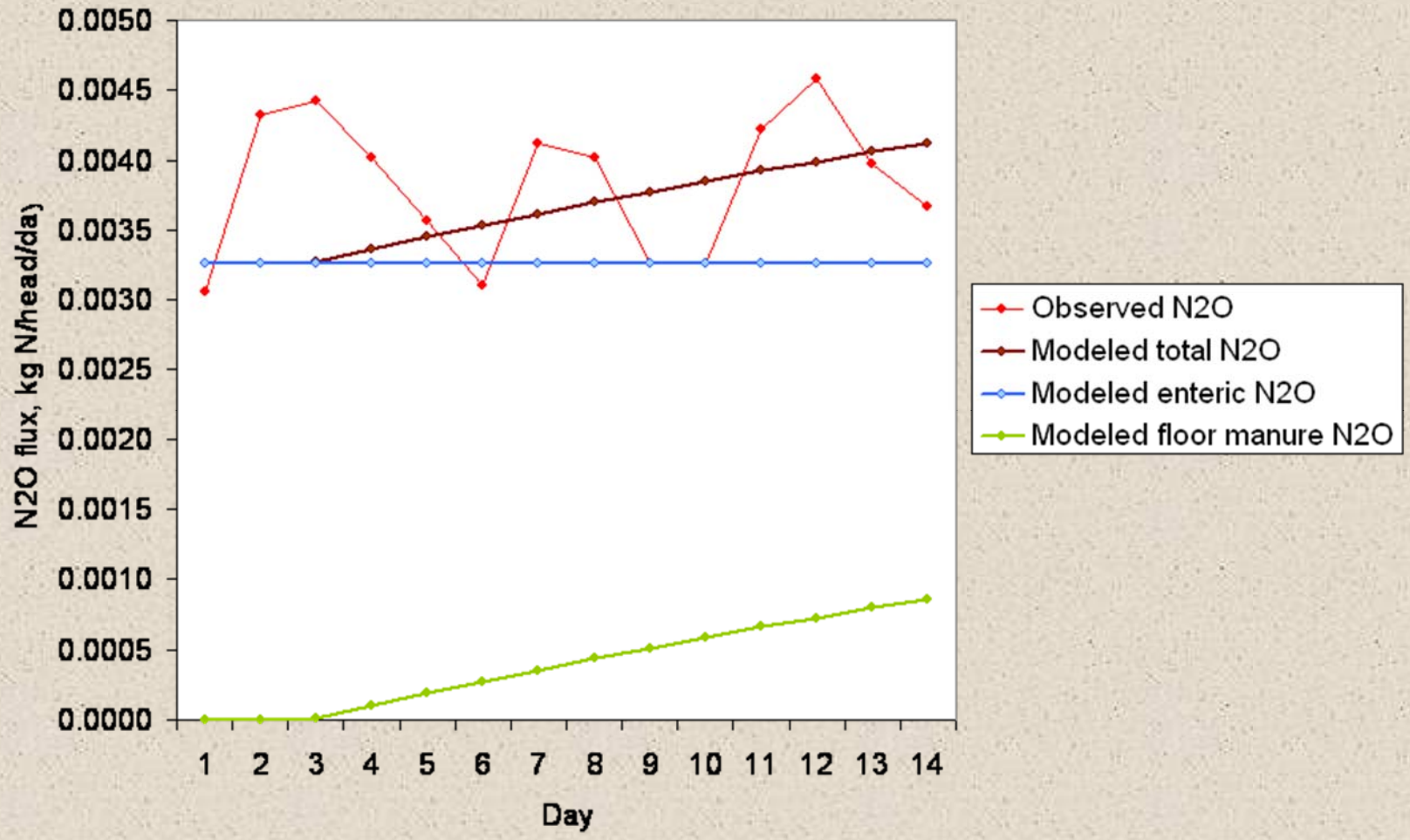
Compost Results



Manure-DNDC Validation

- Tested against 4 datasets:
  - 3 California dairy,
  - 1 swine facility in NC (mass balance study).
- Results are encouraging…need more testing to estimate model uncertainties

Cattle Pen Enclosure Study



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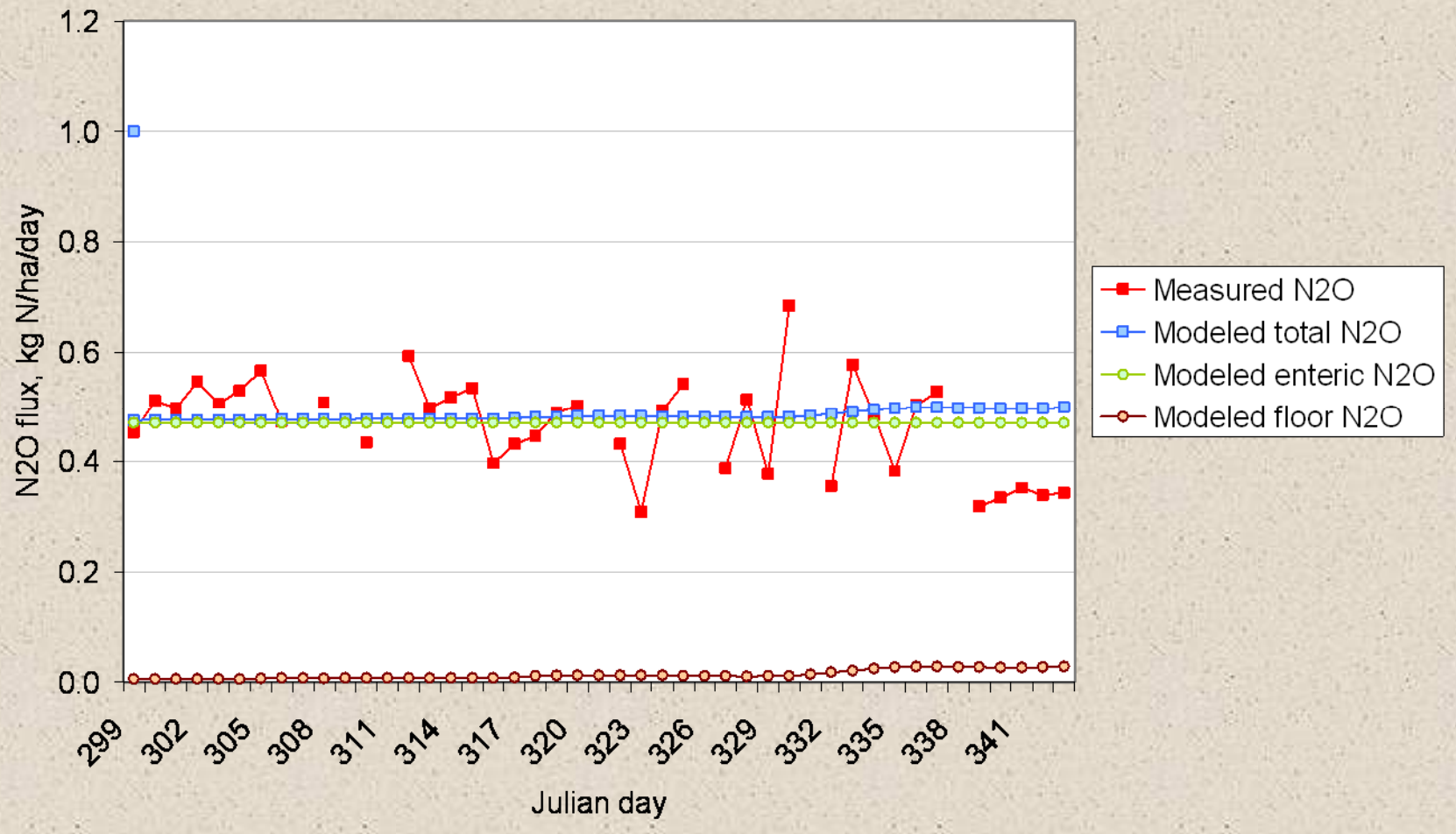
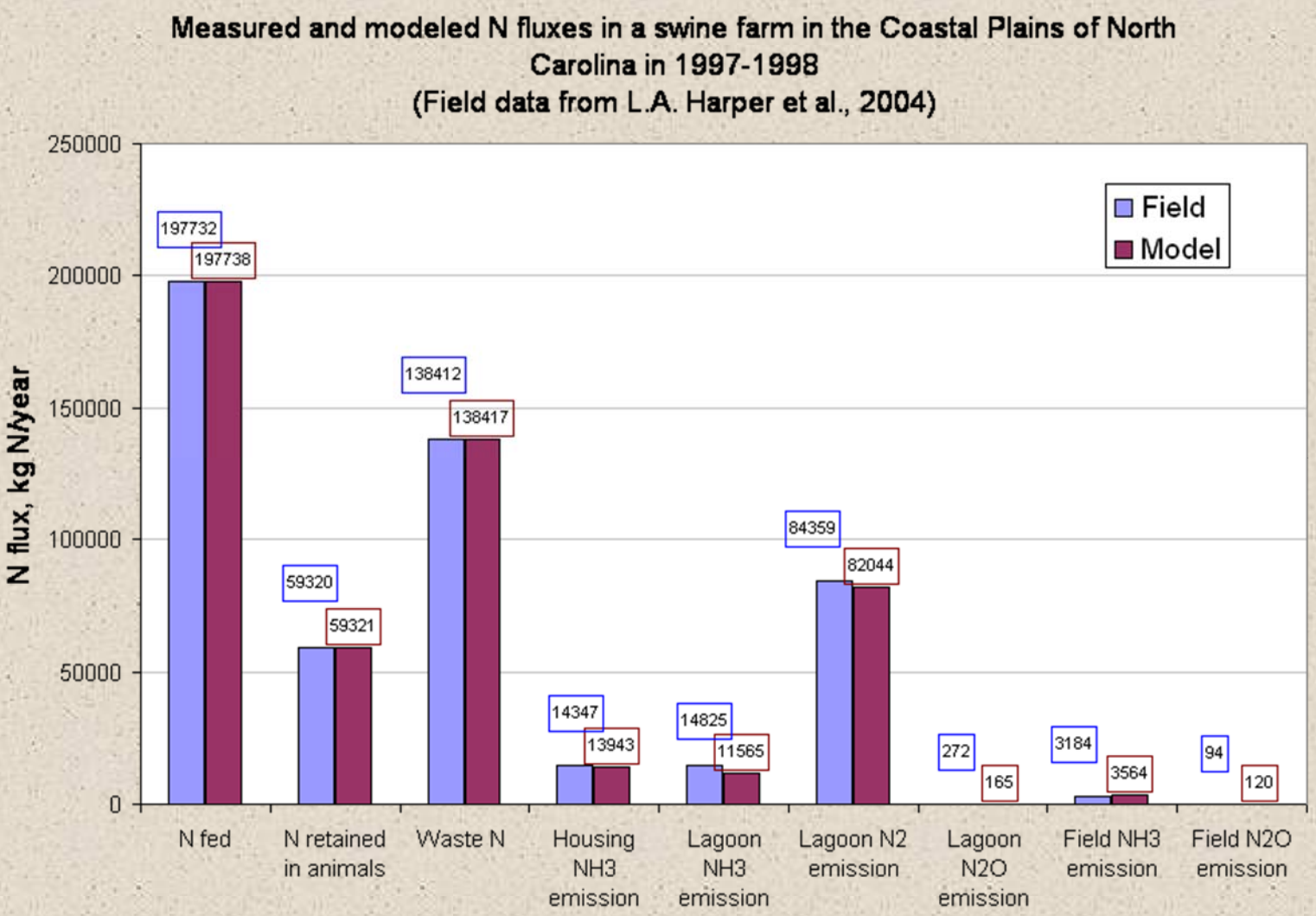
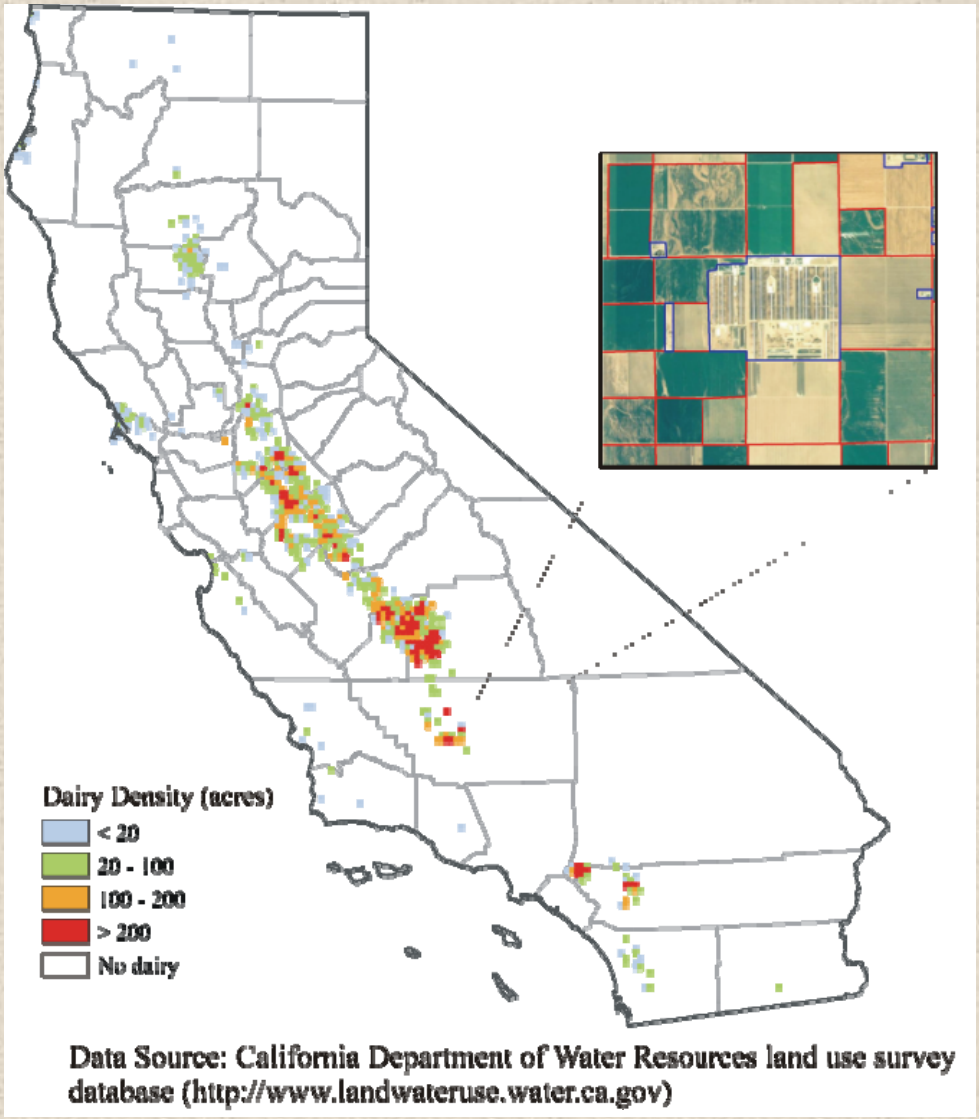
CSUF Drylot


1.2
1.0
0.8
0.6
0.4
0.2
0.0
N2O flux, kg N/ha/day
299
302
305
308
311
314
317
320
323
326
329
332
335
338
341
Julian day
Measured N2O
Modeled total N2O
Modeled enteric N2O
Modeled floor N2O

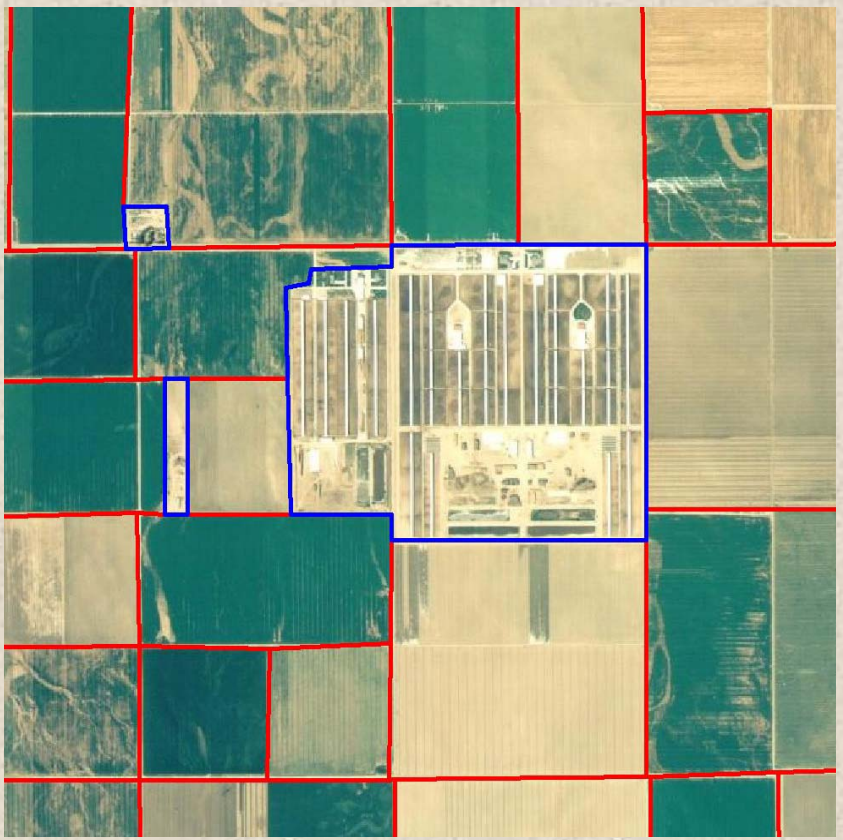
NC Swine Mass Balance Case



GIS databases were constructed to support regional simulations for CA dairies



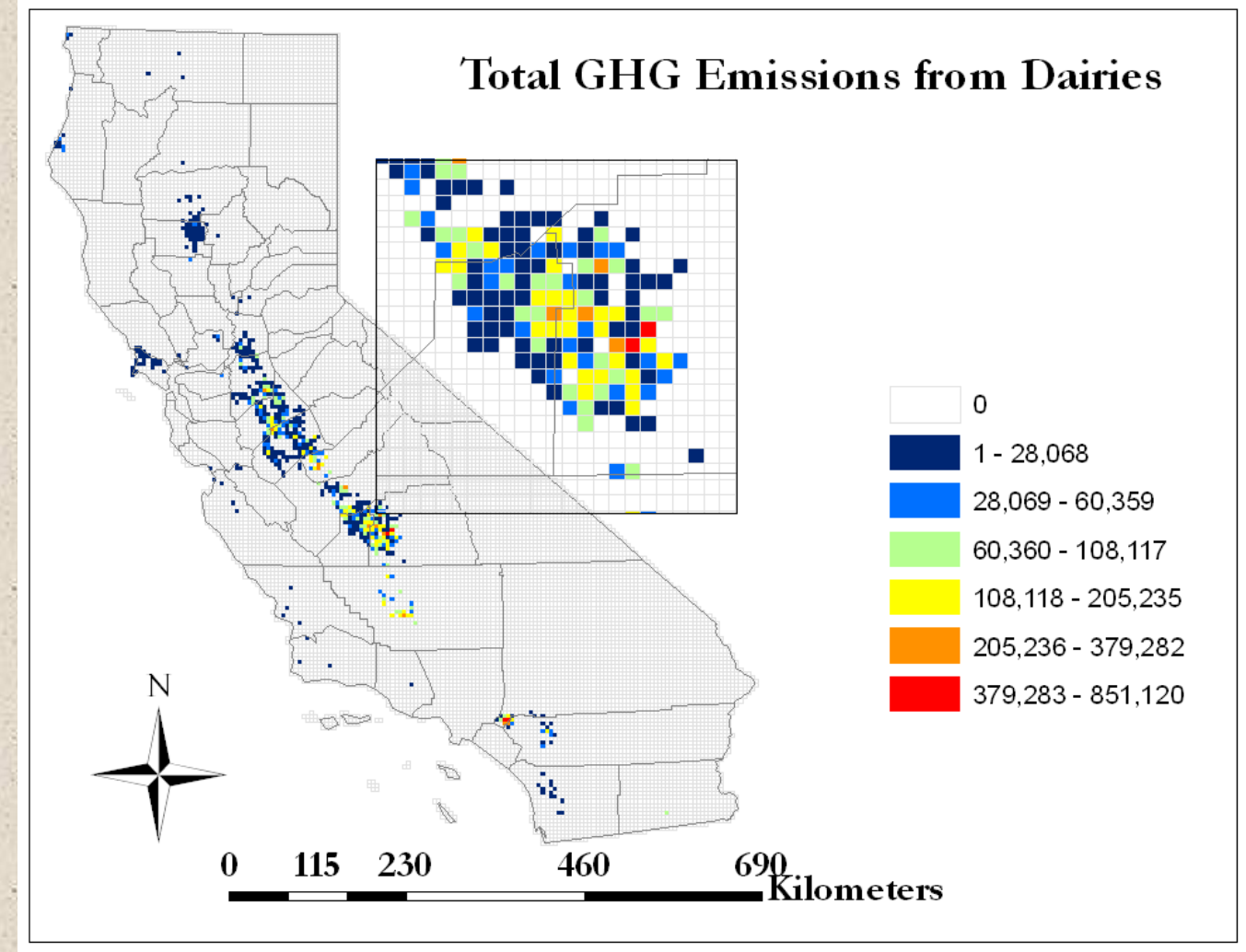
Climate, soil, livestock and management information have been collected.



Statewide Simulations…

- Used dairy permit information from SJVAPCD and SCAQMD to define manure management systems by town and county.
- Ran site level Manure-DNDC simulations for ~250 permitted facilities based on GIS soils and climate.
- Scaled up model results to county and state level

Results: Spatial and Temporal Estimates of CH_4 and N_2O



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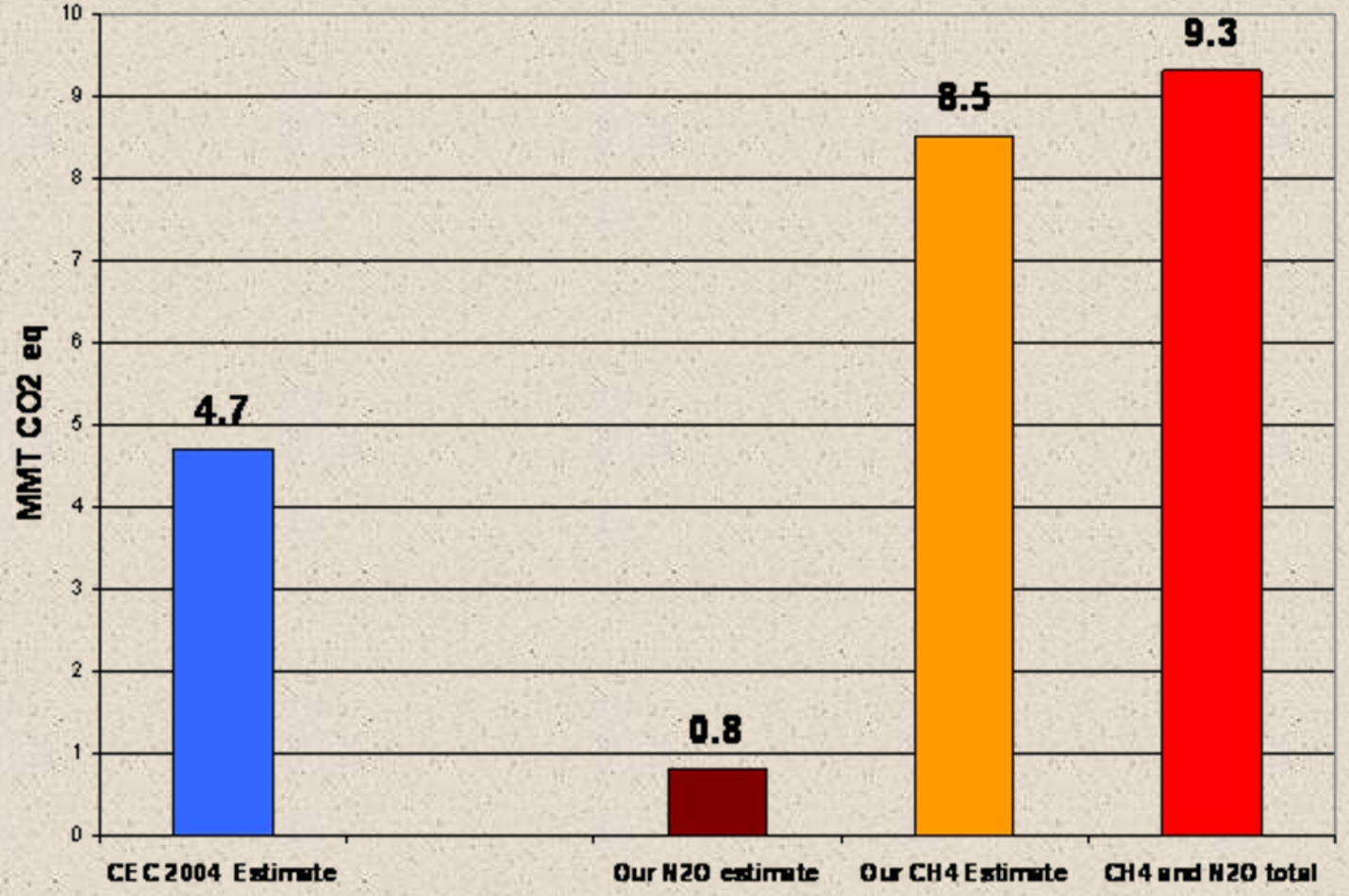
Major Findings: Magnitude of Enteric Source



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Statewide Model Results

EMISSION SOURCE	TOTAL EMISSIONS (MMT CO2Eq)	
Total Enteric	**9.3**	
Enteric CH4		8.5
Enteric N2O		0.8
Total Manure Management	**3.7**	
CH4		1.7
N2O		2.0
Land Application (N2O)*	**6.9**	
*note this includes fertilizer		
Total CH4 and N2O Emissions	**19.9**	

Project Outcomes:

- Biogeochemical process modeling tool for estimating air emissions (CH_4, NH_3, N_2O, NO) and N leaching from California dairies;
- GIS databases on dairies (location, types, herd sizes, manure management, local soils, climate, etc);
- Regional estimates of NH_3 and GHG emissions from California dairies;
- Emission inventory tool for emission inventories ranging from project or facility level up to air-district and state level

Conclusions and Next Steps:

- Modeling framework and system is complete.
- Initial results are encouraging
- Need more validation for testing all components and quantifying uncertainty
  - CSUF ARI project collecting data for 2007/08
  - NMPF funded project to expand to US dairies
  - Field studies with automated chambers for detailed site analyses and other approaches for scaling up of field scale (e.g. Open Path FTIR)

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Acknowledgements:

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Guido Franco

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